Technologies for Structural Damage Analysis

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Accurately simulating the effects of reinforced concrete structures subjected to extreme events, such as blast or aircraft impact, in an efficient and timely manner continues to be extremely challenging. Many large concrete structures contain an extensive amount of rebar, which can be very time consuming for the analyst to model explicitly, using either brick or beam elements. Brick elements provide dimensionality and also allow the use of arbitrary Lagrangian-Eulerian (ALE) schemes where rebar is modeled. However, this requires a very finely resolved mesh. In addition, it is also currently difficult to model a fully-coupled blast simulation of large buildings with substantial beam and column detail. Beam element implementation in ALE3D would allow efficient detailed calculations of large buildings. Furthermore, we need improved metrics of concrete damage or postprocessing techniques. In essence, when the analyst hands over a display of "damage" to the customer, there should be no guessing as to the health of the structure in question.

Project Goals

The main project objective is to enhance our ability to simulate the response of reinforced concrete structures exposed to extreme loading environments. In addition, we need all-encompassing codes, or codes that can handle all aspects of a blast simulation, for example, in one seamless calculation.

Relevance to LLNL Mission

The computational tools implemented for this project will decrease the mesh generation time and the computation time. These tools will significantly enhance our ability to analyze the response of reinforced concrete structures for the Department of Homeland Security and Underground Analysis and Planning Systems, and to assess the vulnerability of

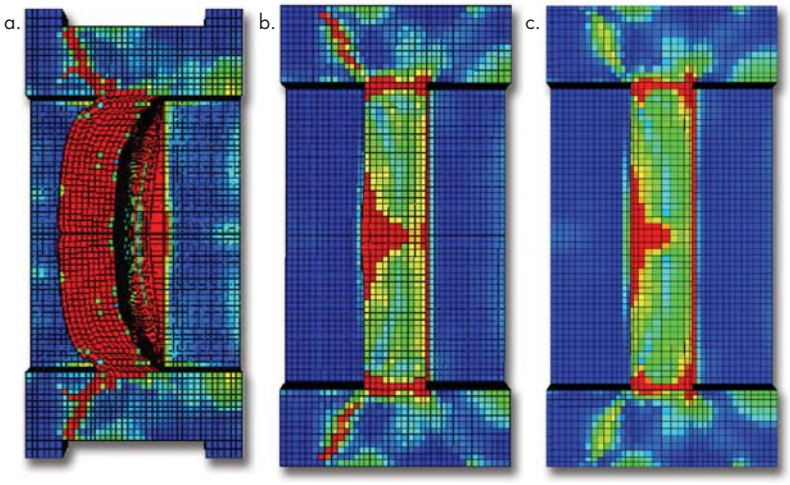

Figure 1. Damage comparison for precision test wall experiment. (a) Test wall with no rebar cage; (b) test wall with rebar explicitly modeled using beam elements in Paradyn; (c) test wall with rebar modeled using new homogenized rebar elements in ALE3D.

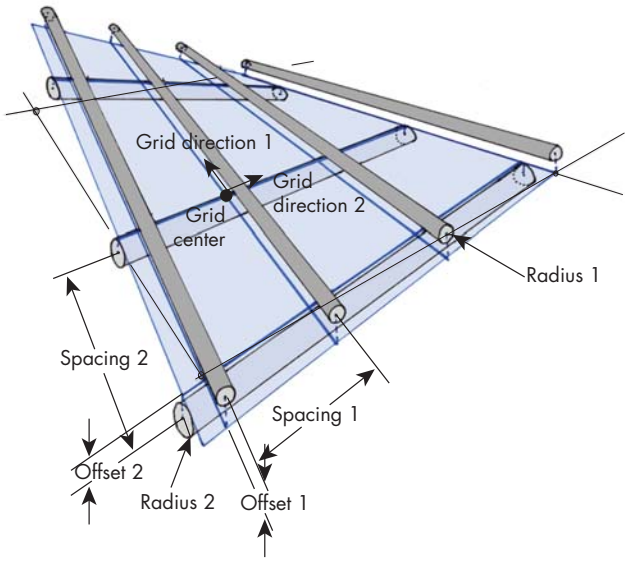

Figure 2. Graphical representation of the rebar detail that FiberGrid will be able to preprocess for ALE3D.

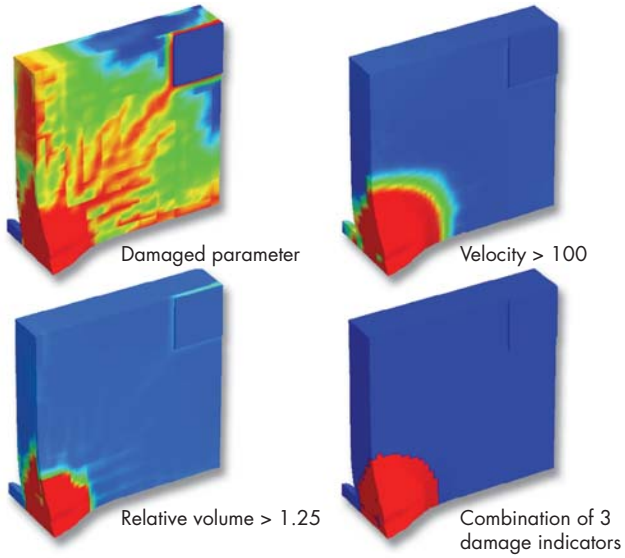

Figure 3. New postprocessing technique in Griz4s that allows the user to combine multiple indicators of damage into one plot.

structures to aircraft impact for DOE and NNSA. This project will also help expand LLNL's expertise in advanced computational analysis.

FY2004 Accomplishments and Results

A composite DTRA Concrete model with homogenized rebar has been coded in ALE3D. This model gives the engineer the capability to simulate strain-rate dependencies, work-hardening, and tensile failure for rebar embedded in concrete. This model will allow advection to occur in the reinforced concrete. Figure 1 shows a comparison of the homogenized rebar model being used on a blast simulation of a reinforced concrete wall, and a comparison with a Paradyn simulation using beam elements to model the rebar.

FiberGrid software (GEN3D) is being generated for use in ALE3D's generator for shaping in rebar grids and also providing the necessary information for the homogenized rebar coding in ALE3D. Figure 2 shows a graphical representation of the type of rebar detail FiberGrid will be able to preprocess.

A new postprocessing technique has been coded into Griz4s for viewing structural failure in reinforced concrete structures. Figure 3 shows how this new technique takes three damage indicators and combines them to give us one that may be an indicator for spall.

The FEAP concrete plasticity model is currently being implemented into NIKE3D and DYNA3D for brick and shell elements.

FY2005 Proposed Work

The proposed work for FY2005 is to implement DYNA3D's beam elements into ALE3D; implement the homogenized rebar model into DYNA3D; validate the homogenized rebar model for ALE3D and DYNA3D; implement FiberGrid into ALE3D's generator for use with the homogenized rebar model; validate FiberGrid; finish and validate the FEAP concrete plasticity implementation into NIKE3D, DYNA3D, and ALE3D; and validate the new damage metric in Griz4s and implement it into ViSit.

Collaboration with the University of California, San Diego will provide LLNL a suite of test data to validate reinforced concrete models.